International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.13 No.01, pp 11-24, 2020

Sequential Batch Reactor for Bio Degradation of Organic Wastewater: A Review

Acharya Neela[1]*, Thakur Chandrakant[1], Chaudhari Parmesh Kumar[1]

[1]Department of Chemical Engineering, National Institute of Technology, Raipur, India

Abstract : Wastewater treatment is challengeable in today's scenario, as it contains many types and varying physical and chemical pollutants which enormously effect the environment and its living beings. The current review elaborates treatment of various organic effluents using sequential batch reactor (SBR). Reactor operating conditions like anaerobic, anoxic and aerobic in single or mixed forms have been covered in the review. Literatures say that SBR can be used to treat many organic, industrial and municipal wastewater (MWW) successfully. Strict effluent characteristics from government force the individuals to treat the effluent to such extent so that it can match the discharge norms of wastewater.
Keywords : Aerobic Process, Anaerobic Process, Biological Oxygen Demand, Chemical Oxygen Demand, Sequential Batch Reactor.

Introduction

To serve the life, water is one of the foremost essential thing. Without water there is no life on earth. Out of 71% water available in earth,5% water is contemporary. It is primarily impure by phylogeny sources like industrial, agricultural and household activities. Owing to growing industries and urbanization, contaminants in water is increasing day by day. Discharging untreated wastewater to water bodies lead to several environmental problems like (i) depletion of dissolved oxygen (DO) of the water stream, which is required to aquatic life (ii) untreated wastewater contains large no of pathogens, or disease causing microorganisms, that causes various epidemic diseases, (iii) it can contain toxic compounds which have harmful effects on human health. Therefore, the treatment of wastewater is very important before leaving it in the natural water bodies.

Wastewater can be treated by using different physical, chemical and biological treatment methods including biological degradation, chemical precipitation, adsorption, ion exchange, reverse osmosis, coagulation, flocculation, etc. All these treatment methods have different performance characteristics and also different direct impacts on the environment.

Conventional activated sludge (CAS) is most commonly used method for treatment of wastewater. This process generally not give water discharge quality, therefore, further treatment is required. Moreover, excessive amount of sludge produced in this process is one of the major drawbacks. The sludge produced is highly tough to stabilize and dewater[1]. Due to this, effective methods are needed that can produce low sludge to reduce the

DOI= http://dx.doi.org/10.20902/IJCTR.2019.130102

prices related to sludge dewatering and sludge production. SBR and MBR is advance process to that of CAS, which give better water quality and low sludge generation. Regulation in operating conditions like DO and sludge retention time (SRT) and addition of chemicals to reduce biomass growth are some options to reduce biomass production[2].SBR is a biological treatment method and its application has increased significantly than other biological treatment methods is due to (i) inherent flexibility in cycle time can be regulated and different organic load can be treated, (ii)ease of operation and less area is required (iii) low treatment cost (iv) low sludge generation[3-5]. SBR treatment system consists of five sequencing operation: filling of wastewater to the reactor (fill phase); degradation of organic matter (react phase); settling of biomass (settle phase); withdrawing of treated water from reactor (draw phase) and keeping the reactor to inoperative condition (idle phase)for about 15 – 30 minutes for preparation of next cycle[6]. SBR in various forms have been originally used for reduction of COD and BOD from different types of wastewaters[7-10]. The SBR has several benefits to the activated sludge. The aim of this paper is to highlight the operation and use of SBR for treatment of wastewater.

Sequential Batch Reactor

A SBR is sort of activated sludge method applied for the wastewater treatment. According to 1999 U.S. EPA report[11], SBR operates based on space and ASP based on time. The operation of SBR has been described by Irvine and Davis[12]. SBR can treat wastewater that is biodegradable, which can be directly generated from process or it can be pretreated by anaerobic digestion. To reduce organic load i.e COD and BOD the air is bubbled through wastewater and activated sludge mixture. The treated effluent could also be appropriate for discharge to water receiving bodies like river, pond, surface waters or presumably to be used towards land. There are many configurations of SBRs, the fundamental method is analogous. SBR installation may consist of one or additional tanks which is operated mainly as fully mixed reactors. The raw waste (influent) enters the one end and treated water (effluent) goes out the opposite. In multiple tank system one tank is operated as settled and decant mode while opposite in aerating and filling mode. This helps to mix the incoming influent and the returned activated sludge. High amount of pollutants like BOD, COD, TS, Total Kjeldahal Nitrogen (TKN), phosphorous, oil and grease removal have been observed in treatment of various effluents like Tannery[13], Paper mill[14], Coke oven[15], Distillery[16], Brewery[17,18], Diary[19-25], Piggery[26,27], Petrochemical[28], Textile[29-34], Palm oil refinery[35], complex chemicals[36], etc.

The SBRs are used for (i) Anaerobic (ii) Aerobic treatment of wastewater which is described below.

Anaerobic Process

Anoxic SBR are often used for anaerobic treatment processes. During this case, the reactors are purged of oxygen by flushing with nitrogen. As the microorganisms multiply and die, the sludge at intervals in the tank increases with time which is removed using sludge pump. The mass or age of sludge in the tank is closely monitored at time intervals, because it has a vigorous impact on the treatment method. The sludge is allowed to settle till clear water is obtained at the top of the reactor as supernatant, mostly 20-30% of the tank contains sludge. The clear liquid can be further treated or it can be used as water source to vegetables.

Aerobic Process

When oxygen is added to the SBR, it enhances the multiplication of aerobic microorganism so that they can consume the nutrients and hydrocarbons. The method converses ammonia to chemical group and nitrate forms is referred to as nitrification. COD and BOD also reduced by oxidation bacteria. The sludge attached with microorganisms is allowed to settle in the tank. The aerobic microorganism still multiply till the dissolved oxygen is virtually spent. The schematic diagram of SBR process is presented in Figure 1.The utilization of SBR in wastewater treatment is presented in Table 1.

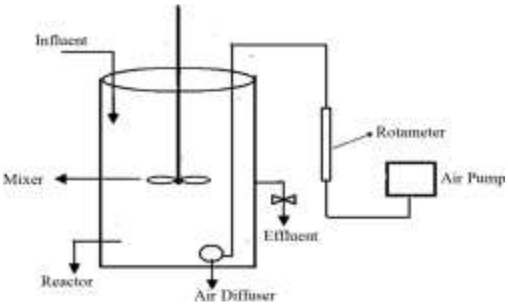

Figure 1: Schematic diagram of SBR

The hydraulic retention time (HRT) and fill time have been found to major effect on SBR operation which is discussed below.

Effect of HRT

HRT play an important role during wastewater treatment in SBR. HRT is defined as the time required by the wastewater to pass through the system. Effect of HRT on degradation of pollutants from coking wastewater (CWW) was studied in a pilot plant SBR[37]. Average values of COD = 1100 – 1700 mg/dm^3, Phenol = 185 – 253 mg/dm^3, thiocyanide = 210 – 485 mg/dm^3, ammonia nitrogen = 532 – 567 mg/dm^3 contained in CWW. For HRT = 58 – 225 h, COD removal was in between 69 to 81 %, phenol removal was 97 to 99 %, SCN^- removal was 90 to 98 %, NH_3-N removal was 41 to 85 %. In the study, 58 h HRT was found to be optimum. A study done by Kushwaha et al.[38]for the treatment of diary waste water showed 96.5 % COD removal and 64.61 % TKN removal at HRT = 24 h. Similar studies were performed by Thakur et al.[39]to treat petroleum refinery wastewater (PRW) which had a COD = 350 ± 25 mg/dm^3 and TOC = 70 ± 10 mg/dm^3. HRT was varied in between 0.56 to 3.33 days. Among these studies, HRT = 0.83 d gave maximum 80 % COD and 83 % TOC removal. The reason for lower COD and TOC removal at HRT> 0.83 was due to lower growth rate of microorganisms and accumulation of older cell.

Table 1: Applications of SBR in wastewater treatment

S. No.	Wastewater	Experimental Setup/ Waste properties	Parameters observed	Result/ Conclusion	Reference
1	Wastewater from pulp and paper mill	The Laboratory scale reactor consists of four 4 dm^{3}capacity with the use of aquarium type air pump for aeration. Minimum of 2 mg/dm^3 of DO level were maintained. The experiments were performed at 25– 30 °C. Wastewater characterized as COD of 1200-1400 mg/dm^3, BOD of 550-790 mg/dm^3, TSS of 200-500 mg/dm^3 and pH varies form 6.2-6.6.	Effect of MLSS concentration, volume exchange rate, aeration time, temperature and cycles per day.	COD removal efficiency under the optimized condition was 93 %, at MLSS = 4500 mg/dm^3, aeration time = 5 h per cycle, temperature = 30 °C	Tsang et al.[14] (2007)
2	Landfill leachate.	The reactors, with a working volume of 6 dm^3 each were used. The stirrer was operated at 36 rpm. The leachate was supplied to the reactors for 4 h of the cycle at 0.125 dm^3/h (SBR 1), 0.2 dm^3/h (SBR 2), 0.5 dm^3/h (SBR 3) and 0.75 dm^3/h (SBR 4). All the four SBRs were operated at HRT of 12, 6, 3 and 2 d.	COD and BOD_5 removal efficiency and bio mass yield co- efficient was observed.	The process had littleeffect to BOD_5 removal efficiency, while better COD removal efficiency.	Kulikowska et al.[56] (2007)
3	Treatment of municipal solid	The comparison of SBR with normal working procedure (Control reactor) to the SBR using zeolite powder to increase the activity of sludge was	Operational efficiency of both the SBRs in removing COD,	The addition of Zeolite powder enhanced the activity of the	He et al.[57] (2007)

	wastewater	performed. The reactors used were of 0.3 m diameter and 0.6 m height with an effective volume of 31.1 dm^3. The characteristics of the wastewater used in the study was SS = 94-212 mg/ dm^3; COD = 274-421 mg/ dm^3; NH_4^+N = 25.5-44.2 mg/ dm^3; TN = 33.5-68.7 mg/ dm^3; TP = 2.65-4.85 mg/ dm^3 and pH = 6.67-7.86. The Zeolite concentration was maintained 1000 mg/ dm^3.	TN, NH_4^+N and TP. Variation of DO in operating cycle and comparison of sludge characteristics	sludge and specific O_2 utilization rate. The pollutants like COD, TN, NH_4^+N and TP was removed in shorter length of time. The zeolite contained reactor treated 1.22 times more wastewater than normal SBR.	
4	Treatment of synthetic phenolic wastewater.	Two identical SBRs of working volume of 5 dm^3 were used.It was operated with fill, react, settle and draw periods in the ratio of 4:6:1:1 for a cycle time of 12 h. First reactor was aerated during fill and react phase, while the second was aerated only in the react phase.	The performance of SBR was evaluated for aerated and unaerated fill phase.	The fill mode was not effective for phenol and COD reduction; The kinetic studies found to high concentration of phenol has an inhibitory effect on the degradation rate of phenol.	Chan and Lim[58] (2007)
5	Landfill leachate	The SBR bioreactor was made of plexiglas with operating volume of 50 dm^3 It was operated with the cycle time of 24 h with fill phase 2 h, anoxic phase 2 h, aeration 18 h, settling 1 h, decant and idle period 1 h.	Removal of COD BOD and N, Change of alkalinity and cycle time study	Removal efficiencies of COD = 93.28%, BOD = 98.76%, TN = 84.74% and NH_4^+-N = 9.21%	Zhou et al.[59] (2006)
6	Synthetic wastewater	Three identical SBRs were used in the study with anaerobic/aerobic sequence to reduce COD and phosphorus. The working volume of the reactor was 4 dm^3 with the operating cycle of 14 h.	COD and phosphorus removal.	Complete removal of 20 mg/dm^3 PO_4–P was achieved in 35 d of operation. The COD removal efficiency was 90%	Sarioglu[60](2005)
7	Synthetic wastewater	Four cylindrical SBR of 127 cm height and 5 cm diameter with a working volume of 2.5 $dm^3$was used with 5 mints for filling and 5 mints for decantation. Total operating cycle was 4 h.The air flow rate was maintained to 3 dm^3/min.	Granular characteristics and sludge settlability.	Granules were successfully cultivated and settled in 5 mints	Qin[61] (2004)
8	Synthetic wastewater	The SBR was operated under different conditions. It consists of a 5 dm^3 working volume with microprocessor controlled for aeration, pH, agitation and DO. SBRs performance was done with three different operating schemes i.e. one with three step operation: anaerobic (An)/ anoxic (Ax)/ oxic (Ox); four step operation: An/Ox/ Ax/Ox and five step operation: An/Ax/Ox/Ax/Ox	COD, phosphate and nitrogen removal.	The most of the COD and ammonium were removed during the first three steps. However, for removal of phosphate-P and nitrate-N five-step operation was required.	Kargi and Uygur[62] (2003)
9	Petroleum refineries	SBR with working volume 15 dm^3 at 15°C was used. One third of the	Amonical nitrogen and phenol	Upto 95%, NH^+ and phenol removal	Silva et al.[63]

		reactor was filled with inoculums. The operation cycle from fill to decant phase was 6 h in which 4.3 h was for react phase and the rest was distributed in other phases.	removal.	was noted.	(2002)
10	Phenolic	Application of granulated activated carbon (GAC)in SBR to treat wastewater with phenolic shock loading was studied. Two reactors of 12 dm^3 and operating volume of 10 $dm^3$was used. The adsorbent used was lignite based granular activated carbon with 0.75 mm diameter.	Adsorption characteristics of GAC,step up shock loading, short term fluctuation and stepwise augmentation for phenol removal.	SBR with GAC was found to high stability to phenol shock loading and worked as a buffer by adsorbing the high strength of influent phenol and as a supporting media for microorganisms	Vinitnant harat et al[64] (2001)
11	Petrochemi cal wastewater	The three phase experimentswere performed for study of different parameters in four reactors of glass cylinder have capacity of 3.5 dm^3. The working volume of SBRs was 2 dm^3. The flow rate of wastewater was 2 dm^3/d and 0.4dm^3/d. The HRT was maintained to 2 d and SRT to 10 d.	Phenol removal at different operating parameters.	Degradation of phenol reached to less than 0.1 mg/dm^3 from 950 mg/dm^3.	Hsu[65] (1986)

Effect of Fill Time

The reactor needs to give feed which has to be- treated. Amount of total feed given in particular time is known as fill time. Thakur et al.[39]studied the fill time variation for COD and TOC removal of PRW. In fill time of 0.5, 1 and 2 h, respectively, COD removal efficiencies were 58 %, 68 % and 74 %,and TOC removal were 28 %, 51 % and 59 %. Pollutants removal rate was low initially for higher fill time, which was increased when time proceeded. Effect of fill time was also performed by Kushwaha et al.[38]. Forfill time = 0 to 2 h, they have also found increase in COD reduction with increase in fill time. DO was found to increase with increase in fill time. Yu andGu[40], didfill time studies for treatment of synthetic phenolic wastewater in the two SBRs which was operated at aerated fill and un-aerated fill conditions. When phenol concentration was low (< 400 mg/dm^3), the SBR was operated at un-aerated fill condition performed better to that SBR operated with aerated fill condition. It was also noted that at higher phenol concentration (> 800 mg/dm^3), accumulation of phenol during fill period had became inhibitory to microorganisms causes low phenol removal efficiency and low growth of dispersed biomass. The studies show,fill strategies should be selected according to wastewater composition, biodegradability and concentration of toxic substances in wastewater.

As we know that SBR has been utilized for treatment of various effluents. The work done by various researchers are presented below:

Sarfaraz et al.[41]conducted anoxic treatment for degradation of phenol in SBR using granular denitrifying sludge. The different cycle lengths and influent phenol concentration was main variable parameters. In the processupto 80% phenol was degraded from its initial value of 1050 mg/ dm^3at cycle length of 6 h, which was corresponded to 6.4 g COD/dm^3.d. When phenol concentration was increased, the phenol and COD removal efficiencies was decreased. Tomei et al.[42]performed the biodegradation of 4-nitrophenol (4NP) in a SBR. In the experiments, both long feed phase and high biomass concentration showed much effective to reduce the 4 NP. Sahinkaya and Dilek[43]investigated the biodegradation kinetics of 4-chlorophenol (4-CP) and 2,4-dichlorophenol (2,4-DCP) separately in batch reactors and in mixed SBR. Fang et al.[44]investigated removal efficiency of phenol from synthetic wastewater using anaerobic thermophilic condition (55°C). Maximum phenol removal 99% was achieved at HRT of 40 h.

Shariati et al.[45]have treated synthetic petroleum wastewater in a SBR at different HRT, similarly,Kutty et al.[46]also used six different SBR to treat PRW having COD concentration in the range of 500-750 mg/dm^3. Experiments were performed at anaerobic and aerobic modes with a 24 h cycle in 2 dm^3 reactor. The process gave COD removal of 91%, 91%, and 88% respectively, for aerobic reactor, combined anaerobic-aerobic reactors and aerobic mixed.

Derlon et al.[47]studied the formation of aerobic granular sludge in SBR for MWW treatment.Granular sludge formation was possible at low upflow velocities during anaerobic feeding phase. In a study by Alvarez et al.[48]for treatment of DSin a two stage anaerobic pilot plant technique, total COD removal of 49% - 65% obtained with a 35.1% methane conversion from influent COD.

Gutiérrezet al.[49] did the lab scale removal of carbon and nitrogen from dairy wastewater using SBR. They used a 15dm^3 reactor for treatment and found the aeration time 4.5 h to optimum. During operation, the HRT was 4 days and 20 days. In the process, COD reduction reached to 97% and total nitrogen to 90%. Similarly,studied byKushwahaet al.[38] for treatment of dairy wastewater, the optimization of parameters like fill time, HRT, sludge disposal was done.Up to 97.05 % COD removal and 63.08 % TKN removal was observed.Rajabet al.[50]investigated the performance of a lab scale anaerobic/aerobic SBR for poultry slaughterhouse wastewater. The anaerobic reactor of volume 12 dm^3 was used but the aerobic reactor volume varied according to the flow rate. Experiments were performed at room temperature of 26-28°C. The results obtained were overall COD removal of 97% ± 2%, NH_3-N removal 98% ± 1.3%, oil and grease removal 90% ± 11% and total suspended solids (TSS) removal 96% ± 3%.

Gonza´lez et al.[51]worked on the photo fenton oxidation and sequential batch biofilm reactor. For 200 mg/ dm^3 of antibiotic sulfamethoxazole containing water, the 75.7% TOC removal obtained. Biodegradation of organic compounds Dichlorodiethyl ether (DCDE) was performed in SBR. For this, removal of organic was 92% in term of COD and 95% in term of TOC. Miqueletoet al.[52]analysed the performance of anaerobic SBR for COD removal of synthetic glucose solution. At optimum condition, 93-97% COD removal was seen for 500 mg/dm^3 glucose solution. Evaluation and characterization of granular formation was performed by Jang et al.[53]in aerobic and anoxic conditions. After 50 days of operation, the size of granules was found to be 1 ± 0.35 to 1.39 ± 0.45 mm. COD removal and nitrification efficiency was 95% and 97% respectively.

Frigon et al.[54]treated the cheesy whey wastewater sequentially in anaerobic and aerobic SBR.They found, in first 48 cycles (each cycle of 2, 3 and 4 days) with organic loading rates of 0.56, 1.04 and 0.78 gCOD/ dm^3/d, for 2, 3 and 4 days, respectively; COD removal was 89 ± 4%, 97 ± 3% and 98 ± 2%. Whereas, in the second 16 cycles (each cycle of 2 days) with organic loading rate 1.55 gCOD/dm^3/d, COD removal was 88 ± 3%.High strength semiconductor wastewater using fenton oxidation was performed in SBRbyLinet al.[55]. In the process95% COD and 99% color removal was seen after fenton oxidation with a 5 g/ dm^3 $FeSO_4$ dosageand 45 g/ dm^3 H_2O_2 concentration and 180 min of digestion.

Some of the literatures are listed in Table 2.

Table 2: Wastewater treatment through sequential batch reactor (SBR)

S. No.	Authors	Type of wastewater and initial values (mg/dm^3)	Aerobic / Anaerobic Process	Reactor configuration and operating conditions	Results at optimum condition % Removal, values (mg/dm^3)
1	Maran˜o ´n et al.[37] (2008)	Coke wastewater COD =1 303 Phenol = 207 SCN^- = 244 NH_4 - N = 489	Aerobic condition	Height = 6 m Volume = 1500 dm^3 HRT = 58 h System composed biological SBR, stripping unit and homogenization tank	COD = 85% SCN^- = 98% phenol = 99%
2	Jiang et al.[66]	Synthetic wastewater (aniline)	Anaerobic/ aerobic/anoxic	Diameter/Height = 6.67 Volume = 9 dm^3 HRT = 12 h	COD = 95.80% NH_4-N = 83.03% TN = 87.13%

	(2016)	COD = 900	(A/O/A)	DO = 5.5 ± 0.5	TP = 90.95%
3	Kushwaha et al.[38] (2013)	Dairy wastewater COD = 3900 TKN = 113.18	Aerobic condition	Working Volume = 5 dm^3 HRT = 24 h	COD = 96.7% TKN = 76.7%
4	Sarti et al.[67](2007)	Domestic sewage COD = 600-1200	Anaerobic condition	Total Volume = 1.2 dm^3	COD = 65 % Suspended solid = 79%.
5	Sarti et al.[68] (2007)	Domestic sewage COD = 119-701	Anaerobic condition	Total Volume = 1.2 dm^3 Diameter = 1m Height = 1.5m Anaerobic sequencing batch biofilm reactor (ASBBR) immobilized in inert support (polyurethane foam cubes).	COD = 40%–83%
6	Pereira et al.[69] (2009)	Synthetic wastewater. Formaldehyde COD = 31.6 ± 8.7 to 1104.4 ± 130.8	AnSBR	Total Volume = 5 dm^3 Diameter = 0.23 m Biomass immobilized in polyurethane foam cubes. HRT = 212 d Temperature = 35°C cycles = 8 h each	formaldehyde = 99.3% COD = 70.8%
7	Stadler et al.[70] (2015)	Pharmaceutical wastewater	Aerobic, anoxic/aerobic, and microaerobic conditions	Working Volume = 1.8 dm^3 DO = 0.3	COD = 93 ± 2 %
8	Jiang et al.[71] (2016)	Phenolic wastewater. Phenol concentration = 200 to 1400	-	Working Volume = 1 dm^3	Phenol = 100%
9	Akin et al.[72] (2004)	Synthetic wastewater COD = 400 Phosphate = 21 Ammonia = 53	Anaerobic/ anoxic condition	Total Volume = 10 dm^3 SRT = 25 d	Phosphate = 80% Ammonia nitrogen = 98% COD = 97%
10	Gimeno et al.[73] (2016)	Synthetic MWW	Aerobic SBR followed by solar Photocatalytic oxidation	Total Volume = 1.8 dm^3 Nine pharmaceuticals model compounds (acetaminophen ACM, antipyrine ANT, caffeine CAF, ketorolac KET, metoprolol MET, sulfamethoxazole SFX, carbamazepine CARB, hydrochlorothiazide HCT and diclofenac DIC) were analyzed	Single ozonation = 34% Photocatalytic ozonation = 41.3%
11	Liang et al.[74] (2013)	Synthetic wastewater TOC = 550-600 NH_4^+-N = 50	Anaerobic condition	Diameter = 0.1016 m Height = 0.7 m Working Volume = 1.7 dm^3 High pressure system (HP) = 3 bars	Granulation was high at high pressure condition
12	Sharma et al.[75] (2010)	Resorcinol = 50	Aerobic	Diameter = 0.13 m Working Volume = 2 dm^3	Resorcinol = 85.81%

13	Leong et al.[76] (2011)	Synthetic wastewater Phenol = 100-400	Aerobic condition	Working Volume = 28 dm^3 Height = 0.30 m Width = 0.15 m Length = 0.35 m Flow rate = 58 ml/min	-
14	Durai et al.[77] (2011)	Tannery wastewater. COD = 6240, 4680, 3220, 1560	Aerobic condition	Total Volume = 10 dm^3 HRT = 2-3 d	COD = 90.4% Color = 78.6%
15	Rasheed et al.[78] (2010)	Petrochemical wastewater. COD = 40,000, Total Solids = 1700, Dissolved Solids = 700, SS =1000	Aerobic, anoxic, and anaerobic modes	Total Volume = 1dm^3 DO = 2.2 mg/dm^3	-
16	Thakur et al.[39] (2014)	PRW COD = 350 ± 25, TOC = 70 ± 10	Aerobic	Working Volume = 5 dm^3 Fill time = 2h HRT = 0.83 d	COD = 80% TOC = 83%
17	Jang et al.[53] (2003)	Synthetic wastewater COD = 300	Anaerobic/ anoxic	Working volume = 8 dm^3 , Total height = 150 cm, Internal diameter = 10 cm SVI value = 70-90 ml/g	COD = 95%
18	Yang et al.[79] (2003)	Synthetic wastewater COD = 500 NH_4-N = 400, NO_2-N = 20	Aerobic, Anaerobic/ anoxic	4 columns having working volume = 2.4 dm^3 Total height = 80 cm Diameter = 6 cm was operated for 1 year	COD = 95%
19	Prokopov et al.[80] (2014)	Municipal wastewater COD = 274 BOD_5 = 119 Total nitrogen = 25.7 Total phosphorus = 3.8 Suspended solids = 79	Aerobic condition	3 aeration basins of SBR with aerobic sludge stabilization, dewatering and lime conditioning was done	COD = 95.7%, BOD_5 = 96.6%, TKN = 81.3%, TP = 53.7% Suspended solids = 95.7%
20	Xiangwen et al.[18](2008)	Brewery wastewater COD = 22500–32500	AnSBR	HRT = 1 d (60 days operation) A pilot scale ASBR was used for COD removal of wastewater and gas production	COD > 90% Gas production = 2.4 L/d
21	Bao et al.[81] (2009)	Synthetic COD = 1120	Sequencing Biological airlift reactor	Volume = 5 dm^3	COD = 90.6 -95.4 %
22	Yang et al.[82] (2008)	Glucose-synthetic wastewater COD = 1000	SBR	Volume = 2.4 dm^3	COD = 90 %
23	Wang et al.[83] (2008)	Municipal wastewater COD = 400	SBR	Volume = 12 dm^3 HRT = 0.6 d	COD = 83.3 %
24	Sharma	Resorcinol	SBR	Volume = 2 dm^3	Resorcinol = 85.81

	et al.[75] (2010b)			SVI = 252.3 mL/g	%
25	Chin and Ng[35] 1987	Palm oil refinery COD = 1500	SBR	Volume = 2 dm^3 SVI < 100 mL/g	COD = 50 %
26	Fakhru'l -Razi et al.[84] (2010)	Oil field produced water COD = 1300	Membrane-coupled sequencing batch reactor	Volume = 5 dm^3 HRT = 20 d	COD = 90.9 %
27	Jern[85] (1987)	Piggery COD = 2028	SBR	Volume = 8 dm^3 HRT = 24 d	COD = 81 %
28	Kim et al.[86] (2008)	Synthetic waste water COD = 1760	SBR	Volume = 8 dm^3	COD = 93 %
29	Nava et al.[87] (2008)	Stainless steelrinse wastewater COD = 335.4	SBR	Volume = 3 dm^3	COD = 78 %
30	Wang et al.[88] (2007)	2,4-di chloro phenol = 50 -100	SBR	Volume = 4 dm^3 HRT = 8 h	2,4-di chloro phenol = 94 % COD = 95 %
31	Chan and Lim[58] (2007)	Phenol = 10-100	SBR	Volume = 5 dm^3 Cycle time = 12 h	Phenol = 99 %
32	Tomei et al.[42] (2003)	4-Nitrophenol = 320 - 400	SBR	Volume = 5 dm^3 Cycle time = 8 h HRT = 16 h SRT = 16 d	4-Nitrophenol = 98 %
33	Chiavola et al.[89] (2010)	Polycyclic aromatic hydrocarbons = 70	SBR	Volume = 5 dm^3 Cycle time = 168 h HRT = 44 – 77 d	Polycyclic aromatic hydrocarbons = 80 %
34	Monsalvo et al.[90] (2009)	Phenol = 525	SBR	Volume = 2.5 dm^3 Cycle time = 12 h	Phenol = 41 %
35	Papadimitriou et al.[15] (2009)	Phenol = 1400 Cyanide = 100	SBR and CSTR	Volume = 5 dm^3 Cycle time = 12 h HRT = 30 h SRT = 26 d	Phenol andCyanide = 93 %
36	Moussavi[91](2010)	Saline Phenol = 100 - 2000	Granular SBR (GSBR)	Volume = 4 dm^3 Cycle time = 17 h	COD = 92% – 99 % Phenol = 93% – 99 %
37	Tomei and Annesini[92] (2008)	Phenolic, 4-Nitrophenol = 40 – 60	SBR	Volume = 5 dm^3 Cycle time = 8 h HRT = 16 h SRT = 16 d	-
38	Farooqi et al.[93] (2008)	Phenol = 200-1000 and m-Cresol	SBR	Volume = 1.4 dm^3 Cycle time = 6 h	Phenol and m-Cresol = 90 – 95 %

39	Yoong et al.[94] (2000)	Phenolic, Phenol = 312	SBR	Volume = 5 dm^3 Cycle time = 4 h HRT = 10 h SRT = 4 d	COD = 97 %
40	Chiavola et al.[89] (2010)	River Sediments COD = 200 – 4000	Bench-scale, SS (sediment slurry) SBR	Volume = 5 dm^3 Cycle time = 7 h HRT = 70 d	Total PAH (polycyclic aromatic hydrocarbons) = 70 mg/kg (dry weight)
42	El-Gohary and Tawfik[34] (2009)	Textile COD = 595 ± 131	Aerobic	Volume = 4 dm^3 HRT = 5 d	COD = 68.2 %
43	Xiangwen et al.[18] (2009)	Brewery	AnSBR,	Volume = 45 dm^3 HRT = 1 d	COD > 90 %
44	Oliveirae t al.[95] (2008)	Automobile COD = 1400	AnSBBR	Volume = 5 dm^3 Cycle time = 8 h	COD = 88 %
45	Neczaj et al.[25] (2008)	Dairy and Leachate	Aerobic	Volume = 3.5 dm^3 Cycle time = 24 h, HRT = 12 d	COD = 98.4 %
46	Wang et al.[88] (2007)	Brewery COD = 239	Aerobic	Cycle time = 6 h	COD = 88.7 %
47	Tsang et al.[14] (2007)	Paper Mill COD = 1200 - 1400	Aerobic	Volume = 4 dm^3 HRT = 1.6 – 3 d	COD = 93.1 ± 0.3 %
48	Mohan et al.[24] (2007)	Dairy COD = 10400	AnSBR	Volume = 2.3 dm^3 Cycle time = 12 h HRT = 1 d	COD = 65 %
49	Ganesh et al.[13] (2006)	Tannery COD = 1908	Aerobic	Volume = 8 dm^3 Cycle time = 12 h HRT = 2 d	COD = 80 - 82 %

Conclusions

Following conclusions are drawn from the review

1. SBR can be applied for the treatment of almost all the industrial and MWW with wide variety of organic (COD) contents.
2. It is better to conventional activated sludge process in terms of space requirement and extent of pollutant removal.
3. SBR can bear shock load of organics, thus it can be used at low and high organic contents in wastewater.
4. It can be used at anaerobic, anoxic and aerobic conditions.
5. Sludge generation is less so management of sludge is easy.

References

1. Mowla D, Tran HNand Allen DG. A Review of the Properties of Biosludge and Its Relevance to Enhanced Dewatering Processes. Biomass Bioenergy, 2013; 58: 365–378.
2. Foladori P, Andreottola G, Ziglio G. Sludge Reduction Technologies in Wastewater Treatment Plant. IWA Publishing, London, 2010.

3. Blackburne R, Yuan Z, Keller J.Demonstration of nitrogen removal via nitrite in a sequencing batch reactor treating domestic wastewater.Water Res.,2008; 42:2166-2176.
4. Coelho M, Russo C, Araujo O, Optimization of sequencing batch reactor for biological nitrogen removal. Water Res.,2000; 34:2809-2817.
5. Mikosz J, Ptaza E,Kurbiel J.Use of computer simulation for cycle length adjustment in sequencing batch reactor.Wat. Sci. Tech.,2000; 38:60-76.
6. Dague RR, Habben CE, Pidaparti SR.Initial studies on the anaerobic sequencing batch reactor.Wat. Sci. Tech.,1992; 26:2429-2532.
7. Danesh S, Oleszkiewicz JA.Use of a new anaerobic-aerobic sequencing batch reactor system to enhance biological phosphorus removal.Wat. Sci. Tech.,1997; 35:137-144.
8. Carucci A, Majone M, Ramadori R, Rossetti S. Biological phosphorus removal with different organic substrates in an anaerobic/aerobic sequencing batch reactor.Wat. Sci. Tech.,1997; 35:161-168.
9. Colunga AM, Martinez SG. Effects of population displacements on biological phosphorus removal in a biofilm SBR.Wat. Sci. Tech.,1996; 34:303-313.
10. Colmenarejo MF, Bustos A, Garcia MG, Borja R,Banks CJ. An analysis of the factors that influence biological phosphorus removal (BPR) in a sequencing batch anaerobic/aerobic reactor.Bioprocess Eng.,1998; 19:171-174.
11. Wastewater Technology Fact Sheet, Sequencing Batch Reactors, United States Environmental Protection Agency, Office of Water Washington, D.C.EPA 932-F-99-073, 1999.
12. Irvine RL, Davis WB. Use of sequencing batch reactor for wastewater treatment-CPC International, Corpus Christi, TX, Presented at the 26th Annual Industrial Waste Conference, Purdue, University, West Lafayette, IN, 1971.
13. Ganesh RG, Balaji R, Ramanujam A. Biodegradation of tannery wastewater using sequencing batch reactor—respirometric assessment.Bioresour. Technol.,2006; 97:1815-1821.
14. Tsang YF, Hua FL,Chua H, Sin SN, Wang YJ. Optimization of biological treatment of paper mill effluent in a sequencing batch reactor.Biochem. Eng. J.,2007; 34:193-199.
15. Papadimitriou CA, Samaras P, Sakellaropoulos GP. Comparative study of phenol and cyanide containing wastewater in CSTR and SBR activated sludge reactors.Bioresour. Technol.,2009; 100:31-37.
16. Farina R, Cellamare CM, Stante L, Giordano A, International Symposium of Environmental Health Engineering, ANDIS 067,2004; 23-26.
17. Wang SG, Liu XW, Gong WX, Gao BY, Yu HQ, Hua ZD. Aerobic granulation for 2,4-dichlorophenol biodegradation in a sequencing batch reactor.Bioresour. Technol.,2007; 98:2142-2147.
18. Xiangwen S, Dangcong P, Zhaohua T, Xinghua J. Treatment of brewery wastewater using anaerobic sequencing batch reactor (ASBR). Bioresour. Technol.,2008; 99:3182-3186.
19. Dugba PN,Zhang R. Treatment of dairy wastewater with two-stage anaerobic sequencing batch reactor systems - Thermophilic Versus Mesophilic Operations. Bioresour. Technol.,1999; 68:225-233.
20. Whichard DP, Nancy D, Love G. Nitrogen Removal from Dairy Manure Wastewater Using Sequencing Batch Reactors, July 16, 2001.
21. Omil F, Juan M,Arrojo GB,Mendez R. Anaerobic filter reactor performance for the treatment of complex dairy wastewater at industrial scale.Water Res.,2003; 37:4099-4108.
22. Mohseni BA,Bazari H. Biological treatment of dairy wastewater by sequencing batch reactor. Iranian journal of environmental health science & engineering,. 2004; 1:65-69.
23. Sirianuntapiboon S,Jeeyachok N,Larplai R. Sequencing batch reactor biofilm system for treatment of milk industry wastewater. J. Environ. Manage.,2005; 76:177-183.
24. Mohan S,Venkata V, Babu L, Sharma PN. Anaerobic biohydrogen production from dairy wastewater treatment in sequencing batch reactor (AnSBR): Effect of Organic Loading Rate.Enzyme Microb. Technol.,2007; 41:506-515.
25. Neczaj E,Kacprzak M,Kamizela T, Lach J,Okoniewska E. Sequencing batch reactor system for the co-treatment of landfill leachate and dairy wastewater.Desalination,2008; 222:404-409.
26. Jern NW. Aerobic treatment of piggery wastewater with the sequencing batch reactor.Biol. Waste, 1987; 22:285-294.
27. Su JJ, Kung CM, Lin J, Lian WC, Wu JF. Utilization of sequencing batch reactor for in situ piggery wastewater treatment. J. Environ. Sci. Health A,1997; 32 (2):391-405.

28. Hudson N,Doyle J,Lant P,Roach N, Bruyn BD,Stai C. Sequencing batch reactor technology: the key to a BP Refinery [Bulwer Island] Upgraded environmental protection system – a low cost lagoon based retro-fit.Wat. Sci. Tech.,2001; 43:339-346.
29. Shaw CB, Carliel CM,Wheatley AD. Anaerobic/aerobic treatment of coloured textile effluents using sequencing batch reactors.Water Res.,2002; 36:1993-2001.
30. Fongsatitkul P,Elefsiniotis P, Yamasmit A,Yamasmit N. Use of sequencing batch reactors and fenton's reagent to treat a wastewater from a textile industry.Biochem. Eng. J.,2004; 21:213-220.
31. Kapdan IK,Alparslan S. Application of anaerobic–aerobic sequential treatment system to real textile wastewater for colour and COD removal.Enzyme Microb. Technol.,2005; 36:273-279.
32. Abu-Ghunmi LN,Jamrah AI. Biological treatment of textile wastewater using sequencing batch reactor technology.Environ. Model.Assess.,2006; 11:333-343.
33. Isik M,Sponza DT. Biological treatment of acid dyeing wastewater using a sequential anaerobic/aerobic reactor system anaerobic/aerobic sequential treatment of a cotton textile mill wastewater. Enzyme Microb. Technol., 2006; 38:887-892.
34. El-Gohary F, Tawfik A. Decolorization and COD reduction of disperse and reactive dyes wastewater using chemical-coagulation followed by sequential batch reactor (SBR) process. Desalination,2009; 249:1159-1164.
35. Chin KK,Ng WJ. Palm oil refinery effluent treatment by sequencing batch reactors.Biol. Waste,1987; 20:101-109.
36. Mohan SV, Chandrashekara NR,Krishna KP, Madhavi BTV,Sharma PN. Treatment of complex chemical wastewater in a sequencing batch reactor (SBR) with an aerobic suspended growth configuration.Process Biochem.,2005; 40: 1501-1508.
37. Maran˜o´n E, Va´zquez I,Rodrı´guez J,Castrillo´n L, Ferna´ndez Y,Lo´pez H. Treatment of coke wastewater in a sequential batch reactor (SBR) at pilot plant scale.Bioresour. Technol.,2008; 99:4192-4198.
38. Kushwaha JP, Srivastava VC,Mall ID. Sequential batch reactor for dairy wastewater treatment: Parametric optimization; kinetics and waste sludge disposal.J. Environ. Chem. Eng.,2013; 1:1036-1043.
39. Thakur C, Srivastava VC, Mall ID. Aerobic degradation of petroleum refinery wastewater in sequential batch reactor. J. Environ. Sci.Health A,2014; 49:1436-1444.
40. Yu HQ,Gu GW. Treatment of phenolic wastewater by sequencing batch reactors with aerated and unaerated fills.Waste Manage.,1996; 16:561-566.
41. Sarfaraz S, Thomas S, Tewari UK, Iyengar L. Anoxic treatment of phenolic wastewater in sequencing batch reactor. Water Res.,2004; 38:965-971.
42. Tomei MC,Annesini MC,Luberti R, Cento G, Senia A. Kinetics of 4 nitrophenol biodegradation in a sequencing batch reactor. Water Res.,2003;37:3803-3814.
43. Sahinkaya E, Dilek FB. Effect of feeding time on the performance of a sequencing batch reactor treating a mixture of 4-CP and 2, 4-DCP. J.Environ. Manage.,2007; 83:427-436.
44. Fang HHP, Liang DW, Zhang T, Liu Y. Anaerobic treatment of phenol in wastewater under thermophilic condition.Water Res.,2006; 40: 427-434.
45. Shariati SRP, Bonakdarpour B, Zare N,Ashtiani FZ. The effect of hydraulic retention time on the performance and fouling characteristics of membrane sequencing batch reactors used for the treatment of synthetic petroleum refinery wastewater.Bioresour. Technol.,2011; 102:7692-7699.
46. Kutty SRM, Gasim HA, Khamaruddin PF, Malakahmad A. Biological treatability study for refinery wastewater using bench scale sequencing batch reactor systems.WIT Trans. Ecol. Envir., 2011; 145:691-699.
47. Derlon N, Wagner J, Costa RHRD,Morgenroth E. Formation of aerobic granules for the treatment of real and low-strength municipal wastewater using a sequencing batch reactor operated at constant volume. Water Res.,2016; 105:341-350.
48. A´lvarez JA,Armstrong E, Go´mez M, Soto M. Anaerobic treatment of low-strength municipal wastewater by a two-stage pilot plant under psychrophilic conditions.Bioresour. Technol.,2008; 99:7051-7062.
49. Gutiérrez MS, Ferrari A,Benítez A, Hermid S, Canetti RM, 2nd Mercosur Congress on Chemical Engineering, 4th Mercosur Congress on Process Systems Engineering 1-10, 2004.

50. Rajab AR, Salim MR, Sohaili J, Anuar AN, Salmiati, Lakkaboyana SK. Performance of integrated anaerobic/aerobic sequencing batch reactor treating poultry slaughterhouse wastewater.Chem. Eng. J.,2017; 313:967-974.
51. Gonza´lez O,Esplugas M,Sans C, Torres A,Esplugas S. Performance of a sequencing batch biofilm reactor for the treatment of pre-oxidized sulfamethoxazole solutions. Water Res.,2009; 43:2149-2158.
52. Miqueleto AP, Rodrigues JAD, Ratusznei SM, ForestiE,Zaiat M. Treatment of easily degradable wastewater in a stirred anaerobic sequencing batch biofilm reactor.Water Res.,2005; 39:2376-2384.
53. Jang A, Yoon YH,Kim IS, Kim KS, Bishop PL. Characterization and evaluation of aerobic granules in sequencing batch reactor.J. Biotechnol.,2003; 105:71-82.
54. Frigon JC, Breton J, Bruneau T, MolettaR,Guiot SR. The treatment of cheese whey wastewater by sequential anaerobic and aerobic steps in a single digester at pilot scale.Bioresour. Technol.,2009; 100:4156-4163.
55. Lin SH, Jiang CD. Fenton oxidation and sequencing batch reactor (SBR) treatments of high-strength semiconductor wastewater.Desalination,2003; 154:107-116.
56. Kulikowska D, Klimiuk E,Drzewicki A. BOD_5 and COD removal and sludge production in SBR working with or without anoxic phase.Bioresour. Technol.,2007; 98:1426-1432.
57. He SB, Xue G, KongH,Li X. Improving the performance of sequencing batch reactor (SBR) by the addition of zeolite powder.J. Hazard. Mater.,2007; 142:493-499.
58. Chan CH, Lim PE. Evaluation of sequencing batch reactor performance with aerated and unaerated fill periods in treating phenol-containing wastewater.Bioresour. Technol.,2007; 98:1333-1338.
59. Zhou S, ZhangH, Yong S. Combined treatment of landfill leachate with fecal supernatant in SBR. J. Zhejiang Univ. Sci. B, 2006;7:397-403.
60. Sarioglu M. Biological phosphorus removal in a sequencing batch reactor by using pure cultures. Process Biochem.,2005; 40:1599-1603.
61. QinL, Liu Y. Effect of settling time on aerobic granulation in sequencing batch reactor. Biochem. Eng. J.,2004; 21:47-52.
62. Kargi F, Uygur A. Nutrient removal performance of a five-step sequencing batch reactor as a function of wastewater composition.Process Biochem.,2003; 38:1039-1045.
63. Silva MR, Coelho MAZ, Araujo OQF. Minimization of phenol and ammonical nitrogen in refinery wastewater employing biological treatment.Termica Engineering, Special Edison,2002; 33-37.
64. Vinitnantharat S, Cha WS, IshibashiY, Ha SR. Stability of biological activated carbon-sequencing batch reactor (BAC-SBR) to phenol shock loading.Thammasat I.J.S.T.,2001; 6:27-32.
65. Hsu EH. Treatment of a petrochemical wastewater in sequencing batch reactors.Environ. Prog.Sustain. Energy,1986; 5:71-81.
66. Jiang Y, Wang H, ShangY andYang K. Simultaneous removal of aniline, nitrogen and phosphorus in aniline-containing wastewater treatment by using sequencing batch reactor.Bioresour. Technol.,2016; 207:422-429.
67. Sarti A,Fernandes BS, ZaiatM, Foresti E. Anaerobic sequencing batch reactors in pilot-scale for domestic sewage treatment.Desalination,2007; 216:174-182.
68. Sarti A, Garcia ML, ZaiatM, Foresti E. Domestic sewage treatment in a pilot-scale anaerobic sequencing batch biofilm reactor (ASBBR).Resour. Conserv. Recy.,2007; 51:237-247.
69. Pereira NS, Zaiat M. Degradation of formaldehyde in anaerobic sequencing batch biofilm reactor (ASBBR). J. Hazard. Mater.,2009; 163:777-782.
70. Stadler LB, Sub L, Moline CJ,Ernstoff AS, Aga AS, Love NG. Effect of redox conditions on pharmaceutical loss during biological wastewater treatment using sequencing batch reactors. J. Hazard. Mater.,2015; 282:106-115.
71. Jiang Y, Wei L,Zhang H, Yang K, Wang H. Removal performance and microbial communities in a sequencing batch reactor treating hypersaline phenol-laden wastewater.Bioresour. Technol., 2016;218:146-152.
72. Akin BS andUgurl A. The effect of an anoxic zone on biological phosphorus removal by a sequential batch reactor.Bioresour. Technol.,2004; 94:1-7.
73. Gimeno O, García-Araya JF, Beltrán FJ, RivasFJ andEspejo A. Removal of emerging contaminants from a primary effluent of municipal wastewater by means of sequential biological degradation-solar photocatalytic oxidation processes.Chem. Eng. J.,2016; 290:12-20.

74. Liang YM, Yang YL, Chang YW, Chen JY, Li CW and Chen JHYSS. Comparison of high pressure and ambient pressure aerobic granulation sequential batch reactor processes. Bioresour. Technol.,2013; 140:28-35.
75. Sharma V, Srivastava VC, KushwahaJPand Mall ID. Studies on biodegradation of resorcinol in sequential batch reactor. Int. Biodeterior. Biodegrad.,2010b;64:764-768.
76. Leong ML, Lee KM,LaiSO and Ooi BS. Sludge characteristics and performances of the sequencing batch reactor at different influent phenol concentrations.Desalination,2011; 270:181-187.
77. Durai G, Rajasimman M andRajamohan N. Aerobic digestion of tannery wastewater in a sequential batch reactor by salt-tolerant bacterial strains.Appl. Water Sci.,2011; 1:35-40.
78. Rasheed QJ andMuthukumar K. Treatment of petrochemical wastewater using sequencing batch reactor. R.T.E.E., NITTTR, Kolkata, 28-29 January 2010.
79. Yang SF, Tay JH andLiu Y. Formation and characterisation of fungal and bacterial granules under different feeding alkalinity and pH conditions.J.Biotechnol.,2003; 106:77-86.
80. Prokopov T, Mihaylova D, Mihalkov N. Biological treatment of wastewater by sequencing batch reactors. E. B.,2014; 5:33-39.
81. Bao R,Yu S,Shi W, Zhang X, Wang Y. Aerobic granules formation and nutrients removal characteristics in sequencing batch airlift reactor (SBAR) at low temperature.J. Hazard. Mater.,2009; 168:1334-1340.
82. Yang SF, Li XY, Yu HQ. Formation and characterisation of fungal and bacterial granules under different feeding alkalinity and pH conditions.Process Biochem.,2008; 43:8-14.
83. Wang D, Li X, Yang Q, Zeng G, Liao DandZhang J. Biological phosphorus removal in sequencing batch reactor with single-stage oxic process.Bioresour. Technol.,2008; 99:5466-5473.
84. Fakhru'l-Razi A, Pendashteh A, Abidin ZZ, Abdullah LC, Biak DRA,Madaeni SS. Application of membrane-coupled sequencing batch reactor for oil field produced water recycle and beneficial Re-Use.Bioresour. Technol.,2010; 101:6942.
85. Jern WN. Aerobic treatment of piggery wastewater with the sequencing batch reactor.Biolog. Wast.,1987; 22:285-294.
86. Kim IS, Kim SMandJang A. Characterization of aerobic granules by microbial density at different COD loading rates.Bioresour. Technol.,2008; 99:18-25.
87. Nava YF, Maranon E, SoonsJandCastrillon L. Denitrification of wastewater containing high nitrate and calcium concentrations. Bioresour. Technol.,2008; 99:7976-7981.
88. Wang SG, Liu XW, Zhang HY, Gong WX,SunXFandGao BY. Aerobic granulation for 2,4-dichlorophenol biodegradation in a sequencing batch reactor.Chemosphere,2007; 69:769-775.
89. Chiavola A, Baciocchi R,Gavasci R. Biological treatment of PAH-contaminated sediments in a sequencing batch reactor. J. Hazard. Mater.,2010; 184:97-104.
90. Monsalvo VM, Mohedano AF, Casas JA,Rodriguez JJ. Cometabolic biodegradation of 4-chlorophenol by sequencing batch reactors at different temperatures.Bioresour. Technol.,2009; 100:4572-4578.
91. Moussavi G, Barikbin B,Mahmoudi M. The removal of high concentrations of phenol from saline wastewater using aerobic granular SBR.Chem. Eng. J.,2010; 158:498-504.
92. Tomei MC,Annesini MC. Biodegradation of phenolic mixtures in a sequencing batch reactor a kinetic study. Environ. Sci. Pollut. Res.,2008; 15:188-195.
93. Farooqi IH, Basheer F,Ahmad T. Studies on biodegradation of phenols and m-cresols by upflow anaerobic sludge blanket and aerobic sequential batch reactor.Global Nest J., 2008; 10: 39-46.
94. Yoong ET, Lant PA,Greenfield PF. In situ respirometry in an sbr treating wastewater with high phenol concentrations.Water Res., 2000; 34: 239-245.
95. Oliveira RP, Ghilardi JA, Ratusznei SM,Rodrigues JAD, Zaiat M,Foresti E. Anaerobic sequencing batch biofilm reactor applied to automobile industry wastewater treatment: volumetric loading rate and feed strategy effects.Chem. Eng. Process,2008; 47: 1374-1383.

*****